Research on Accuracy Enhancement Scheme for Home 3D Printers Based on Vision Sensors

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Abstract. Nowadays, with the rapid development of technology, more and more new technologies are being developed, but how to make these technologies accessible to factories at an affordable price and at a cost that is acceptable to all parties is a huge and complex comprehensive research. This paper focuses on two new technologies. They are 3D printers and vision sensors. After discussing how they work and the advantages and disadvantages about them. This paper focuses on how these two new technologies can be combined to improve the quality of 3D printing, increase the compatibility of building complex geometries, and reduce the reliance on manual calibration. Finally, a model for combining these two novel technologies is presented along with its operational logic. However, the challenges of cost, sensor integration and algorithm optimization will be addressed in further development and finally a partial analysis of how it can be further developed in the future.

Keywords: 3D printer, New technologies, Vision sensors.

1. Introduction

Nowadays, with the development of technology, there are many new technologies. For example, 3D printers and various sensor technologies. However, due to the existence of some technical barriers, these new technologies are mostly used in individual teams of personal research and development and cannot enter today's mainstream industrial production [1]. The main reason for this is that the capital investment in these new technologies is too expensive for most factories to afford to meet the needs of industrialized assembly line production.

This paper is about how these new technologies can be combined to make them cheaper and more industrially viable. Firstly, in this article we will take a closer look at these new technologies, such as 3D printing and sensors, to give us a deeper understanding of how these new technologies work and change the world. Secondly, this paper will analyze the disadvantages and advantages of each technology individually, and summarize them. Finally, this paper will attempt to build an industrial model that combines several new technologies to solve the shortcomings of each technology and to combine their advantages to achieve greater efficiency. The goal of this paper is to try to use a variety of new models to create an industrial model that can achieve high precision and can be used in large-scale industrial production, so that the traditional industrial production can be upgraded to speed up the production rate of the whole society.

2. The theoretical basis

2.1. The 3D printing

Nowadays, 3D printing is a convenient and versatile tool [2]. It's a different kind of printer than we think of. It's not printing on a two-dimensional plane. It is a technique of constructing an object layer by layer based on a digital model (a three-dimensional design file), using an adhesive material such as powdered metal or plastic, through a three-dimensional printer. It can also be referred to as three-dimensional printing.

In terms of printing methods, there are many categories of 3D printers. There are extrusion 3D printers, particle 3D printers, photopolymer 3D printers and so on [3]. The most suitable and inexpensive 3D printer to start with is the fused deposition molding (FDM) type of extrusion 3D printer. This is also the 3D printer that our group will be using. The structure of FDM mechanical system is shown in figure 1.

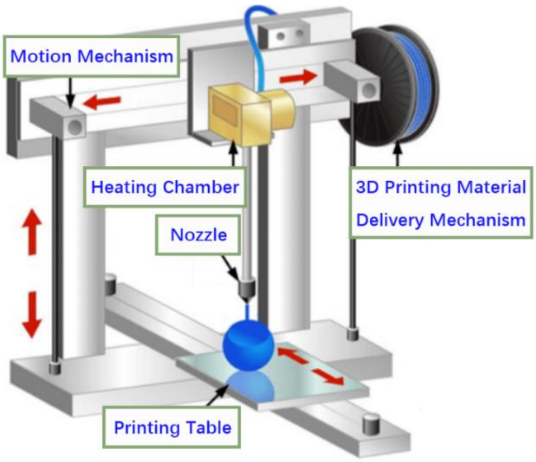

Figure 1. The structure of FDM mechanical system (Photo/Picture credit: Original)

The FDM mechanical system consists of five main parts: the nozzle, the 3D printing material delivery mechanism, the motion mechanism, the heating chamber, and the printing table. The 3D printing material used in the fused deposition process is usually divided into two parts: one is the forming material and the other is the support material. When the printer start printing, the machine melts the low melting point filament material into a liquid through the heating chamber, allowing the molten thermoplastic 3D printing material to be extruded through the nozzle, which moves precisely along the contours of each section of the part, depositing and curing the extruded semi-fluid thermoplastic material into precise thin layers of the actual part, covering the constructed part, and solidifying it rapidly within 1/10s of a second. For each completed model layer, the nozzle rises one layer in height to allow the nozzle to scan the next cross-sectional layer of wire, and so on, layer by layer, until the final layer is deposited, thus building up a solid model or part from bottom to top, layer by layer. In the FDM forming process, each layer is stacked on top of the previous layer, which acts as a positioning and support for the current layer. As the height increases, the area and shape of the layer profile changes, and when the shape changes significantly, the upper layer profile does not provide sufficient positioning and support for the current layer, which requires the design of auxiliary structures - 'supports' - to ensure the smooth implementation of the forming process [4]. The support can be constructed from the same material and is now generally heated independently using dual nozzles, one used to spray the model material to make the part and the other used to spray the support material to make the support, the properties of the two materials are different and it is easy to remove the support after it has been made [5]. The flow rate is smooth and structurally reliable. The 3D printing material delivery mechanism and printheads are therefore usually combined in a push-pull manner to ensure a stable and reliable output of 3D printing material and to avoid disconnection or build-up in multiple places.

FDM printers also have many advantages that traditional manufacturing processes cannot match. For example, the cost of printing with FDM is low. In 3D fused deposition printing, a heating chamber is used instead of the laser used in traditional photopolymerization 3D printing, which makes the equipment required much cheaper. In addition, the 3D printing materials we use are efficient and, because they are heated and melted, there are no toxic or chemical contaminants. This also protects the environment. Secondly, a wide range of materials are available, such as ABS, PC, PPS, and medical ABS in a variety of colors. And once we have printed the prototype parts in wax, they can be used directly in investment casting. Finally, when we can quickly build prototypes. The aim is to quickly complete the subsequent series of tests for the practicality of the product. These speeds up the entire industrial production process.

However, FDM printers also have several drawbacks [6]. For example, there are visible print streaks on the surface of the printed product. The strength of the printed product is low in the direction perpendicular to the section. The need to melt and re-solidify the 3D printing material through the heating chamber can lead to warpage in the printed section, which can affect the accuracy of the whole product.

2.2. The Vision sensor

In the 21st century, sensors are used in all aspects of industrial production. Their main purpose is to detect the information that can be measured in industrial devices, and will detect the information felt, according to certain laws into electrical signals or other forms of information output required to meet the requirements of information transmission, processing, storage, display, recording and control [7]. Finally, the purpose of automatic detection and automatic control is achieved.

Sensors can also be divided into many categories depending on the physical quantity they detect. For example, displacement, force, speed, temperature, flow, gas composition and other sensors. They can also be classified according to their operating principle. Examples include resistance, capacitance, inductance, voltage, Hall, photoelectricity, grating thermocouple and so on [8]. The sensor that our group will use in this project is a vision sensor consisting of a light source, a lens, an image sensor, an analogue/digital converter, an image processor, an image memory, and other components to obtain image information about the external environment.

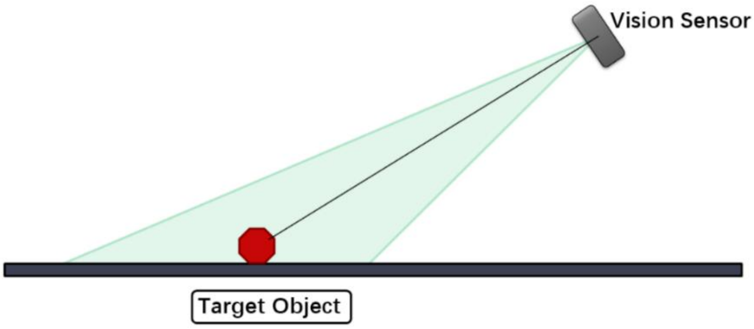

Figure 2. Vision sensors scan target objects (Photo/Picture credit: Original)

The basic principle of a vision sensor is that after capturing an image, the vision sensor compares it with a reference image stored in memory to make an analysis. From figure 2 can see the working principle of the vision sensor. For example, if a vision sensor is set to identify a machine part with eight bolts correctly inserted, the sensor will reject parts with incomplete bolts or parts with misaligned bolts. The vision sensor can also compare the image it captures with a reference image stored in its memory and make an analysis. They are therefore also used in a wide range of industrial applications including inspection, metrology, measurement, orientation, defect detection and sorting. Examples of these applications can be found in automotive assembly, where the bead of glue applied by the robot to the door frame is checked for continuity and correct width. In bottle cap encapsulation, the cap is verified to be completely sealed, the filling level is in the correct position, and foreign objects are detected before the cap is sealed. These examples show that the use of vision sensors for detailed inspection of items can be several times faster than manual inspection [9].

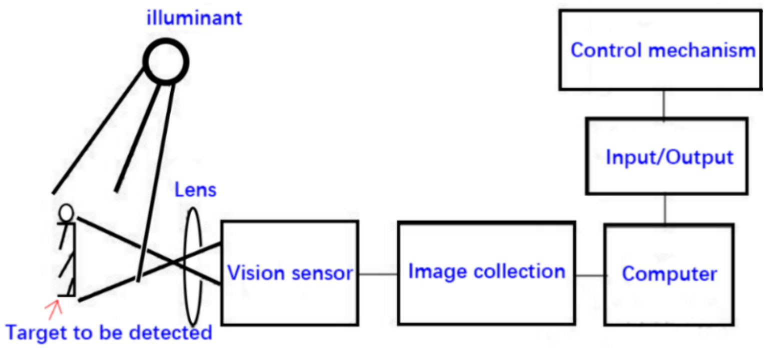

Figure 3. Interaction between vision sensors and computers (Photo/Picture credit: Original)

From figure 3 can see the working logic of the vision sensor. However, there are still many things to avoid when using vision sensors. For example, when using a scan against a reference image stored in memory, it is important to have a pre-determined reference plane to prevent mistake in the comparison rather than normal errors [10]. Secondly, the choice of algorithm for the vision sensor should be based on 2D sensing rather than 3D sensing. This will greatly reduce the error comparison and correction time to speed up the whole correction process.

3. Use vision sensors to improve the accuracy of 3D printers

3.1. Principle analysis

Nowadays 3D printer is a handy and versatile tool, but it still needs to be helped and improved in a few ways. For example, when it can give us excellent efficiency, it loses precision. So, this is something our team is working on. This paper is focusing on improving the accuracy of the FDM (a 3D printer). There are some issues regarding FDM when it comes to printing specific objects. For example, FDM printers usually have the smallest layer height they can achieve, and the level of detail and surface finish produced by the print will be best when the FDM printer reaches the chosen minimum layer height, but the time required is significantly increased. However, when it comes to industrial production, most teams choose the more important layer heights, as these speeds up printing at the expense of accuracy. Choosing a smaller layer height and ensuring proper printer calibration is therefore essential to improve accuracy.

Despite these problems with FDM, there are many solutions available to us. For example, slicer software is an excellent way to improve accuracy, as advanced slicer software allows users to optimize print parameters and generate print paths specific to the object geometry. The adaptive layer heights, variable fill densities, dynamic cooling techniques and precise support generation offered by these software tools improve overall accuracy and part quality. In addition, the use of support structures is essential. Designed support structures provide stability during complex printing processes, avoid gravity-induced deformation, and ensure accurate dimensioning of overhangs and complex features. Strategic placement and easy removal optimize printing accuracy through soluble or detachable supports. Sometimes we print objects with rough surfaces that can affect their functionality; post-processing techniques help to solve this problem. The application of post-processing methods can improve surface finish and address small errors introduced during the printing process. Sanding, priming, and polishing can remove imperfections and enhance the aesthetics of the print.

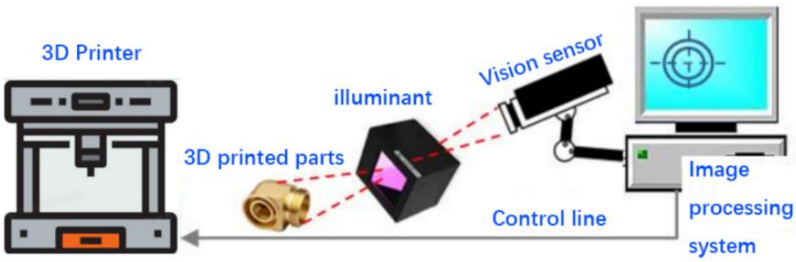

Figure 4. Flow charts that use vision sensors to increase the accuracy of 3D printing (Photo/Picture credit: Original)

However, this paper has found a new way to improve the accuracy of FDM. As illustrated in figure 4. This paper decided to use vision sensors for layer-by-layer monitoring of the 3D printer. At the same time, the print and return the image information to the computer in time. A program then compares the feedback image with the original image of our printed model. In addition, if the contact ratio is not up to standard, i.e., the accuracy we set, the program starts correcting the parameters of the 3D printer to improve the accuracy of the next layer. In addition, this paper uses a fixed-point scanning structure instead of the traditional rotary scanning structure. The advantage of the fixed-point scanning structure is that it allows the vision sensor to point at a point that can be fixed by the computer, which means that it does not need to scan the reference plane and will return the image as a 2D picture, thus reducing the difficulty of comparison.

3.2. Scheme design

The first step in improving the accuracy of 3D printing using scanners is to obtain detailed data about the object to be printed. To do this our team uses modelling software to create a 3D dot matrix of the surface of the object at a fixed point by performing a simulated dot matrix scan of the object to be printed. These dot matrix data are then used to make an accurate reference to the actual 3D printed object.

Once the dot matrix data has been constructed, the digital model is thoroughly analyzed. Complex algorithms are used to extract relevant information from the scanned dot matrix data, such as surface topology, curvature, and geometric features. Image processing techniques are then used to improve the quality of the captured data and eliminate noise and artefacts that may be present in realistic prints.

During the analysis phase, the software algorithm compares the scanned model with the expected design. Deviations between the two are identified and classified, providing valuable insights into potential errors or inaccuracies. By pointing out where the problems lie, the designer can make the necessary adjustments to the printer to optimize the final print.

The analysis between the image scanned by the integrated vision scanner and the original image can also be monitored in real time during the printing process. As the printer advances layer by layer, the system compares the physical output with the digital model, constantly checking for discrepancies. If irregularities or deviations are detected, adjustments can be made instantly, minimizing wasted material, and reducing the need for post-processing.

3.3. Design and modeling of theoretical models

As illustrated in figure 5, our team has improved some of the 3D printer hardware, most notably by introducing laser sensors and implementing intelligent fine-tuning technology. These improvements have revolutionized the 3D printing experience, minimizing errors caused by faults, segmentation levels and other printing inconsistencies.

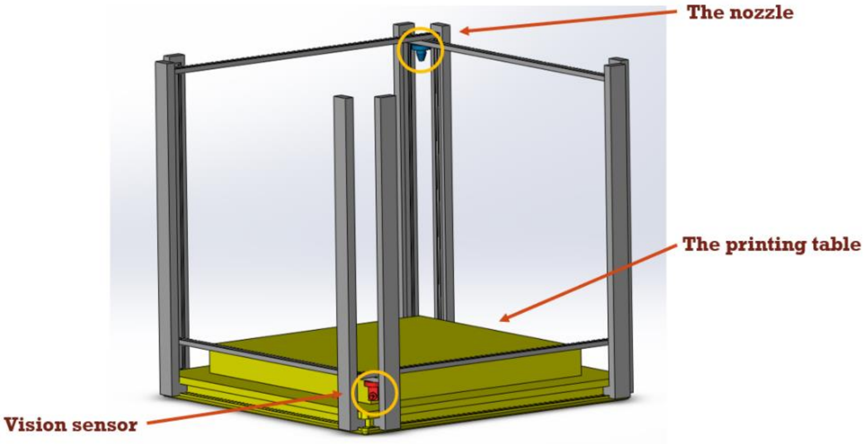

Figure 5. The 3D printer and vision sensor combined model (Photo/Picture credit: Original)

With the addition of the laser sensor the top surface of the 3D printed product will be mapped and scanned in real time. The collected dot data is fed into a programmable microcontroller, which extracts and calculates error values from the raw dot data. These error data points are then removed by fine-tuning the 3D printer and the microcontroller can also compare the error values to predetermined thresholds.

Using an algorithm designed by the team, the system will intelligently adjust the 3D material feed rate and Z-axis height of the printer nozzle. The aim of this iterative process is to ensure that each printed layer matches the ideal model dimensions. The laser sensors are continuously scanned and adjusted throughout the printing process to continuously improve the accuracy and quality of the print.

3.4. Design and construction of theoretical algorithm

This paper has improved the 3D printer for the above situation. It has made massive changes to the process of printing the models. As shown in figure 6, when people feed the 3D model created by the software into the 3D printer, they also scan the model from the software into the computer when the 3D printer has finished printing a layer. The optical scanner moves and scans the object they are printing and compares it to the software model in the computer; nevertheless, a threshold value with a margin of error value is given. After the scan, they found that the part did not exceed the error range value they had set. the 3D printer would automatically turn on the next layer of the print state. However, after scanning, they find that they have obtained an error that exceeds the error range they have set but has not yet reached the threshold. This paper uses the computer to compare the actual object with the model and automatically calculate how to improve it. Once the adjustments have been made, the next layer of the print state is switched on again. Finally, all the models are printed out. However, once they find after scanning that the printing error is too large above our given threshold, the machine is automatically stopped to prevent material loss.

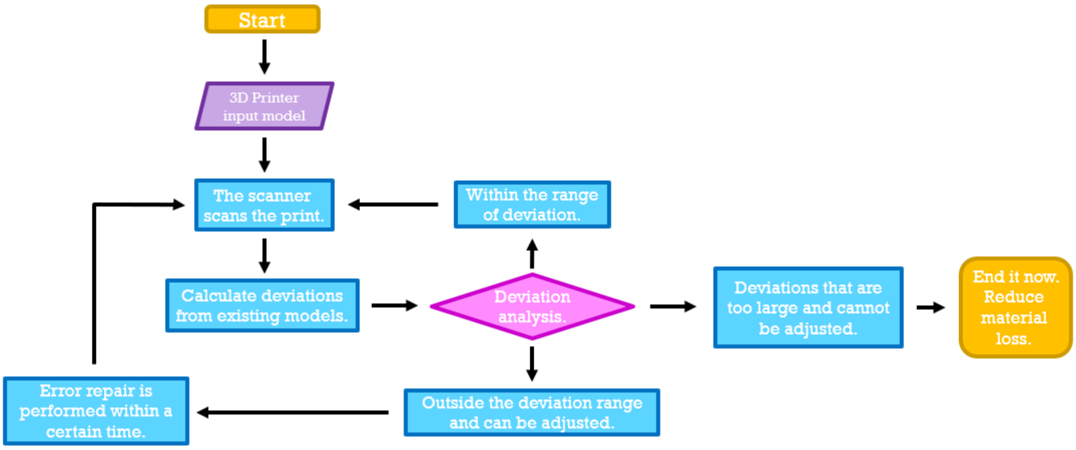

Figure 6. Algorithm tree (Photo/Picture credit: Original)

4. Conclusion

This paper takes a closer look at two new technologies: 3D printing and vision sensors. The research looks at how they work, considering some of their industrial design concepts. The advantages and disadvantages of each new technology are analyzed. The advantages and disadvantages of each new technology are analyzed and, depending on their strengths and weaknesses, they are modified to combine them in a way that solves all the disadvantages of their individual existence. Part of the model design and construction, as well as the construction of the algorithm tree, are also carried out. The aim is to design efficient and cheap industrialized machines.

However, due to the lack of equipment, we have not been able to realize it, which is our biggest regret. But when the opportunity arises in the future, I'm sure I'll continue to push this research forward and try to incorporate more new technologies to make such an industrial machine even more complete. Secondly, due to the recent breakthroughs in AI technology, it is also possible to embed AI deep learning into the machine to give it the ability to think, so that the machine can automatically analyze different problems and find the right solution to achieve the highest overall efficiency.

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